Analysis of Adult Female Mouse (*Mus musculus*) Group Behavior on the International Space Station (ISS)

National Aeronautics and Space Administration

P. Solomides[1], E.L. Moyer[2,3], Y. Talyansky[2,4], S. Choi[2], C. Gong[2], R.K. Globus[2], A.E. Ronca[2,5]

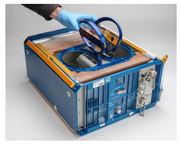
[1]Space Life Sciences Training Program (SLSTP), NASA Ames Research Center, [2]Space Biosciences Division, NASA Ames Research Center, Moffett Field, CA,
[3]Blue Marble Space Institute of Science, Seattle, WA, [4]San Jose State University, San Jose, CA,
[5]Obstetrics & Gynecology, Program in Neuroscience, Molecular Medicine & Translational Science, Wake Forest School of Medicine, Winston-Salem, NC.

ABSTRACT

As interest in long duration effects of space habitation increases, understanding the behavior of model organisms living within the habitats engineered to fly them is vital for designing, validating, and interpreting future spaceflight studies. A handful of papers have previously reported behavior of mice and rats in the weightless environment of space[1,2,3]. The Rodent Research Hardware and Operations Validation (Rodent Research-1; RR1) utilized the Rodent Habitat (RH) developed at NASA Ames Research Center to fly mice on the ISS. Ten adult (16-week-old) female C57BL/6 mice were launched on September 21st, 2014 in an unmanned Dragon Capsule, and spent 37 days in microgravity. Here we report group behavioral phenotypes of the RR1 Flight (FLT) and environment-matched Ground Control (GC) mice in the Rodent Habitat (RH) during this long duration flight. Video was recorded for 33 days on the ISS, permitting daily assessments of overall health and well-being of the mice, and providing a valuable repository for detailed behavioral analysis. We previously reported that, as compared to GC mice, RR1 FLT mice exhibited the same range of behaviors, including eating, drinking, exploration, self- and allo-grooming, and social interactions at similar or greater levels of occurrence. Overall activity was greater in FLT as compared to GC mice, with spontaneous ambulatory behavior, including organized 'circling' or 'race-tracking' behavior that emerged within the first few days of flight following a common developmental sequence, and comprised the primary dark cycle activity persisting throughout the remainder of the experiment. Participation by individual mice increased dramatically over the course of the flight. Here we present a detailed analysis of 'race-tracking' behavior in which we quantified: (1) Complete lap rotations by individual mice; (2) Numbers of collisions between circling mice; (3) Lap directionality; and (4) Recruitment of mice into a group phenotype. This analysis contributes to the first NASA long duration study of rodent behavior, providing evidence for the emergence of a distinctive, organized group behavior unique to the weightless space environment.

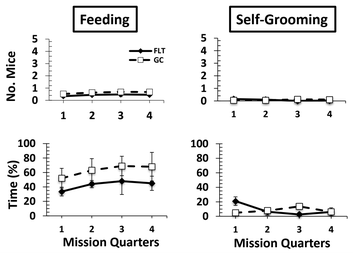
BACKGROUND

- Ten adult (16-week-old) female C57BL/6 mice spent 37 days in microgravity
- Video was recorded and behavior analyzed for 33 days on the ISS
- Comparable numbers of RR1 Flight (FLT) and environment-matched Ground Control (GC) mice exhibited the same key behaviors at similar levels[4].



Rodent Habitat

Camera View

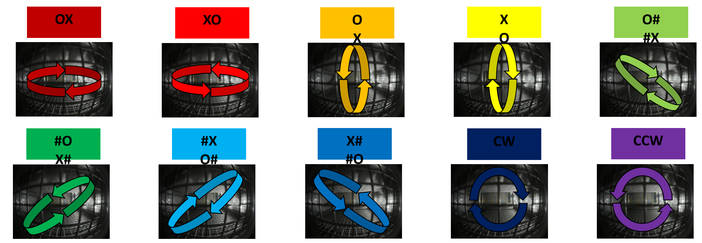


EXPERIMENTAL AIMS

Here we present a detailed analysis of 'circling' behavior that emerged early during the long-duration NASA RR-1 mission on the ISS. Studies of model organisms behaving in space provide new insights into how the unique weightlessness of space alters behavioral phenotypes. The findings are vital for interpreting studies of rodents on the ISS, and guiding future research.

METHODS

Four different measures of circling were quantified:
(1) *Complete rotations*: Hindlimb contact with four walls of the habitat to complete a lap
(2) *Collisions with conspecifics*: Numbers of contacts between one or more mice exhibiting circling behavior
(3) *Directionality*: Identification of predominant circling direction using ten distinct paths the mouse can exhibit, described using vector notation (illustrated below):

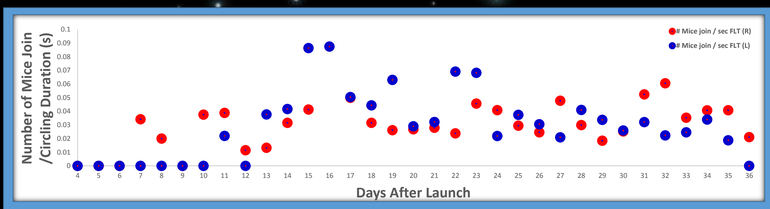


(4) *Recruitment behavior*: Additional mice joining mice performing circling behavior during or immediately after observing the behavior

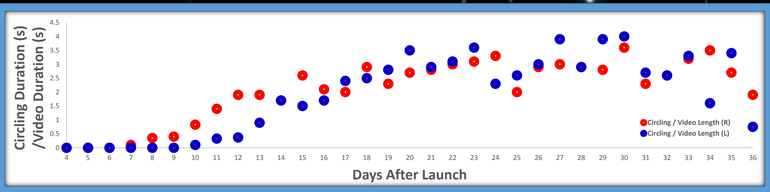
MILESTONES

MILESTONES	Left Compartment	Right Compartment
Flipping	L + 10	L + 8
Circling (1 complete lap)	L + 10	L + 7
Multi-Circling (multiple laps)	L + 10	L + 7
Group Circling (multiple animals)	L + 11	L + 7

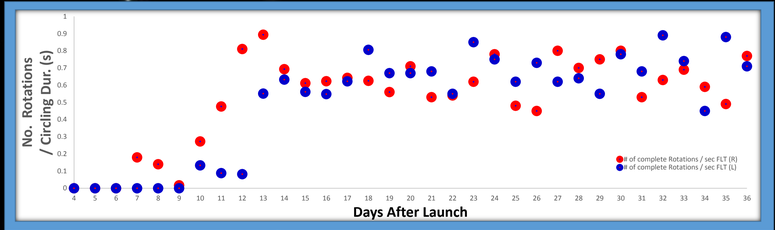
RESULTS: Recruitment Behavior



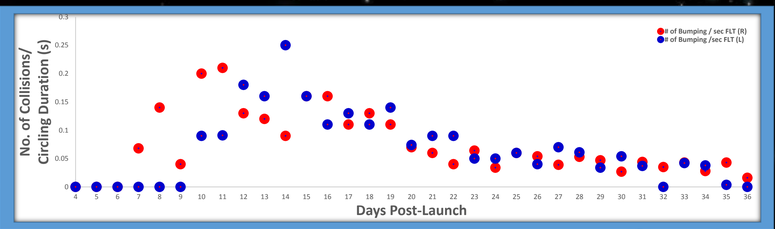
RESULTS: Average No. Mice Circling



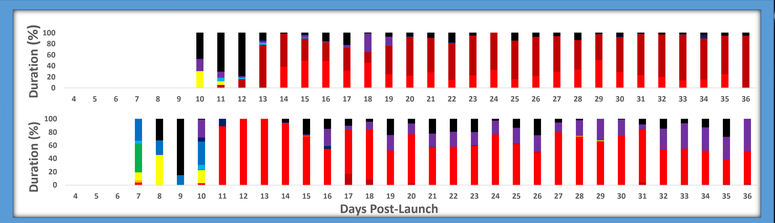
RESULTS: Complete Rotations



RESULTS: Collisions



RESULTS: Directionality



FUTURE INVESTIGATION

- Could this unique circling behavior be associated to stress?
- Could the habitat itself have an effect on circling directionality?
- Could recruitment behavior while circling be associated with mirror neurons?
- Could this unique circling behavior in space be analogous to reward-driven wheel running on Earth?

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We gratefully acknowledge Sue Blumenberg and Alison French for video acquisition, and Janet Beegle and Jeff Smith for project support through the Rodent Research Project and Space Biology Program, respectively, NASA Ames Research Center.